Sheep blowfly strike: the cost of control in relation to risk

K. Lihou, R. Wall

Veterinary Parasitology & Ecology Group, School of Biological Sciences, University of Bristol, Bristol, BS8 1UG, U.K.

Corresponding author: Katie Lihou. Email: kl14574@my.bristol.ac.uk

Short title - Blowfly strike: risk and control

Abstract

Sheep blowfly strike (ovine cutaneous myiasis) is a widespread economic and welfare problem in sheep husbandry in many parts of the world. Strike incidence is determined by a complex interaction of fly abundance, host susceptibility and climate, combined with farmer husbandry and intervention strategies. Sheep farmers adopt a range of approaches to the type and timing of the management used for the control of blowfly strike, the rational basis for which is often not robust. Here a deterministic model, based on existing data relating to fly abundance, seasonal risk and strike incidence, is used to compare the variable costs associated with different strike management strategies. The model shows that not employing prophylactic treatment is the lowest cost strategy only where strike risk is low. In all other circumstances, treating prophylactically incurs lower costs than not doing so, because the deaths associated with strike outweigh the costs of prophylactic treatment. Lamb treatment, in particular, has a substantial effect on strike and cost reduction, since lambs are the most abundant age-class of animals and are at highest risk over the period when fly abundance is greatest. Early season treatment of ewes before shearing is also an important component of the lowest cost strategies, particularly when the blowfly season is extended. While the rational choice of the most appropriate strike management strategy is essential in the context of farm economics, welfare considerations lend added importance to treatment decisions that reduce strike incidence.

Keywords: myiasis, cost-effective, disease, livestock, ectoparasite

Implications

Rational choice of the most appropriate blowfly strike management strategy is essential on lowland sheep farms to reduce variable costs associated with treatment. Strategies which protect ewes at the start of each season and lambs in mid-summer, reduce strike incidence and reduce overall cost. The inclusion of a post-shearing ewe treatment may also be an important component of the lowest cost treatment strategy, particularly when the blowfly season is extended, as is predicted due to changes in climate.

Introduction

Sheep blowfly strike (ovine cutaneous myiasis) is a widespread economic and welfare problem for sheep husbandry in many parts of the world. The primary agent of strike in most of northern Europe is the blowfly *Lucilia sericata* (Wall *et al*., 1992a;

Snoep *et al*., 2004). Eggs are deposited in the wool of the living host and, after hatching, the feeding activity of the larvae causes extensive epidermal tissue damage, anaemia and toxaemia; the resulting lesions rapidly attract further oviposition, leading to death if untreated.

In general, the seasonal incidence of strike in ewes and lambs follows a relatively predictable pattern, determined by the interaction of fly abundance and the factors that influence sheep susceptibility (Broughan & Wall, 2007a,b). *Lucilia sericata* overwinter as diapausing larvae, pupate and emerge as adults in April/May as temperatures increase beyond 9°C each year in Spring (Wall *et al*., 1992b). Flies pass through three or four generations of increasing abundance over summer until short daylengths and cold temperatures return in winter (Pitts & Wall, 2005, 2006). At the start of the summer, relatively low, *L. sericata* abundance may be the main factor limiting strike incidence (Smith & Wall, 1998). Sheep susceptibility is determined by the interaction of wool length, fleece humidity and the accumulation of faeces in the wool, known as faecal soiling (French *et al*., 1996; Broughan & Wall, 2007b). The degree of faecal soiling is affected by the consistency of the faeces and factors that allow its accumulation in the breech region, such as fleece length (French *et al.,* 1996) and this is in turn affected by the gastrointestinal (GI) nematode burden (Broughan & Wall, 2007b). In the spring, oviposition occurs predominantly on ewes, since they carry their long winter fleece, creating a humid microclimate at the skin surface that allows high rates of blowfly egg and larval survival. In mid-summer, ewes are sheared, and this reduces their susceptibility; shearing has been shown to result in a 95% reduction in the risk of ewe strike (Broughan & Wall, 2007a), largely as a result of the reduced humidity in the fleece of the shorn animal. However, the incidence of ewe strikes can increase again towards the end of the season because of the re-growing fleece, particularly if the autumn is warm and wet (French *et al*., 1992; Broughan & Wall, 2007a). For spring-born lambs, the initially short fleece results in lower susceptibility than ewes, but after weaning in summer, a combination of diarrhoea caused by temperature-dependent GI nematode infection and a growing fleece leads to faecal soiling and rapidly increases their susceptibility to strike. Lamb strikes therefore generally increase in incidence from mid-summer onwards.

A range of insecticides are available to control blowfly strike and can be used both prophylactically and reactively (Bates, 2004; Bisdorff & Wall, 2008). These include the organophosphate diazinon, the pyrethroids high cis-cypermethrin, alpha-cypermethrin and deltamethrin and insect growth regulators (IGRs) such as cyromazine and dicyclanil (Wall and Lovatt, 2015). IGRs are specific to arthropods, disrupting larval moulting by interfering with chitin synthesis and cuticle formation. The existing IGRs do not prevent egg laying or hatching but are effective against developing larval stages as they moult. Therefore, they can be used effectively only for strike prevention, not for treatment of established strikes (Graf, 1993). Although the majority of farmers use IGRs for strike control, the lower cost of pyrethroids results in continued popularity (35% of farmers in 2003. Bisdorff & Wall, 2008) while others continue to summer-dip with organophosphate (12% of farmers in 2003; Bisdorff & Wall, 2008) although parasiticide usage patterns may vary substantially with region (Chivers *et al*., 2018).

Despite the widespread use of prophylaxis by most farmers, sheep myiasis still affects more than 75% of farms in the UK with an estimated 1.5% of ewes and 3% of lambs struck each year (French *et al*., 1992; Bisdorff *et al*., 2006). The economic impact of flystrike to the UK sheep industry is therefore considerable with losses due to animal mortality and reduced growth rates leading to additional time spent on farm and costs due to reactive treatment and prophylactic control, as well as the time and labour involved in the frequent inspection of flocks and the need to catch and handle struck animals. Prophylactic treatment may represent a substantial contribution to the cost for each flock, so some farmers will attempt to forgo prophylaxis and rely on vigilance to identify infested animals and then apply reactive therapeutic treatment, particularly in ewes before shearing. However, even a low strike incidence on any farm may significantly increase the costs associated with sheep husbandry which, given that the margin per lamb may be low, is likely to undermine the contribution to farm profit. It is important therefore that farmers are able to understand and compare the relative costs associated with different management strategies to allow them to make informed rational decisions about approaches to animal management.

The aim of the work reported here was to develop a simple model, based on existing data relating to fly abundance, sheep susceptibility, risk and strike incidence to compare the variable cost of a range of potential strike management strategies.

Methods and materials

A deterministic partial budget simulation model was constructed in Excel (Microsoft Corp, Washington US). Partial budget models are commonly used in farm business management to help farmers evaluate the financial effect of incremental change. The model (Figure 1) first used an estimate of the probability of strike (risk) for ewes or lambs, based on the expected pattern of fly abundance and animal susceptibility. Risk was multiplied by the number of ewes and lambs present to estimate the number struck and the mortality was calculated from the numbers struck multiplied by the probability of death from strike.

Operationally, the model considered a lowland breeding flock of 250 ewes, lambing at an average ratio 1.5 lambs per ewe. Blowflies were assumed to emerge in spring in March/April, increase in abundance over summer and enter diapause in October/November (Pitts & Wall, 2005). Ewes were sheared at the end of June. Previous work found that on lowland farms in south west England, where no prophylactic strike control was used, 6–12% of ewes and 6–16% of lambs were struck (Broughan & Wall, 2007a). Hence as a baseline in the present model, under what will be described as the moderate level of strike risk, 8% of untreated ewes and 10% of untreated lambs were considered to be struck over the year. Lambs were born in April, matured and started to be sold to market in July with the last lambs sold off farm in September. The seasonal pattern of strike incidence was as described by French *et al*. (1995) and Broughan & Wall (2007a), with early season strikes in ewes, followed by a post-shearing decline in ewe susceptibility, and a late season increase in ewe strikes associated with the growing fleece (Figure 1). For lambs, the incidence of strike increased over the summer to peak in July and August, followed by declining numbers, as lambs were sold to market (Figure 1).

A strong regional pattern of mortality among struck sheep has been reported, varying between 7.5% in the north and 1.5% in south east England (French *et al*., 1995). Hence, regardless of farmer vigilance, in the current model an average death rate of 5% among struck animals was assumed; all other struck animals, are treated reactively. The loss associated with a lamb death due to strike was estimated at £140 based on the average deadweight value of lamb and the average cost of rearing a lamb (including vaccinations, labour etc.) in a non-significantly disadvantaged area; an area without pasture restriction or rough grazing (Department for Environment, Food and Rural Affairs, 2016 and 2018; Agriculture and Horticulture Development Board, 2018).

The cost of the death of a breeding ewe was estimated to be £200, based upon the cost of rearing a replacement ewe-lamb, plus the current value of a cull ewe (AHDB, 2016, 2017). The labour cost to treat a struck animal was estimated at £10, based on the assumption that finding, removing and treating an infested animal would take one additional hour of farm time (Department of Agriculture, Environment and Rural Affairs, 2018). The cost of insecticide required to treat an infested animal curatively was calculated at £0.16. For struck lambs, an estimated additional cost of £10 was included, based on an anticipated reduction in growth rate and delay in getting struck lambs to market weight, however there is a lack of clear quantitative analysis of the productivity costs associated with strike. No estimate was made for impacts of strike on the fecundity of ewes. The variable costs described above were applied in all model treatment scenarios; fixed costs were not included.

The model was used to estimate the effects of blowfly strike when using different treatment strategies (Table 1). These strategies were based on typical patterns of management used by UK farmers (French *et al*., 1994; Bisdorff *et al*., 2008). For each management strategy, the model used the expected duration of protection from strike based on the label claim of the product in question to reduce the risk to zero, and added the costs of treatment, reduced productivity, labour and deaths. Comparisons were made between an organophosphate (OP) immersion dip, which was considered to give 8 weeks of protection, a long-acting IGR-type product (product A), which was considered to give 16 weeks of protection and a short-acting pyrethroid-type product (product B), which was considered to give 8 weeks of protection. Costs were obtained from a range of current supplier websites. The cost of OP dip was estimated at £0.35 per ewe and an additional £300 was included for dip disposal. OP dip was not applied to lambs. The use of product A was considered to cost £1.50 or £1.00, for ewes and lambs respectively, and product B, £0.65 and £0.40, for ewes and lambs, respectively. The model then examined the impact of zero treatment, or different combinations of these treatments applied either pre- or post-shearing in ewes and in mid-summer (June/July) in lambs, on strike incidence (Table 1).

To explore the impact of strike risk, treatment cost comparisons were made between flocks where the strike risk per month was reduced by half or doubled for both ewes and lambs. To investigate the potential impacts of changes in climate on the economics of strike treatment, the model was modified to extend the blowfly season, bringing fly emergence one month earlier and extending activity to one month later than in the baseline model. Extension of the blowfly season is predicted due to changes in the climate, particularly increased average temperatures (Broughan & Wall, 2007a) which significantly effects blowfly development (Wall *et al*., 1992b), resulting in earlier spring emergence and increased numbers of struck animals (Broughan & Wall., 2007a). In the extended season model, shearing was moved from late June to late May, to reflect changes in management in response to warmer spring temperatures (Morgan & Wall, 2009), but lambing dates were unchanged.

Results

In the baseline scenario, for flocks at moderate risk of strike, with no prophylactic treatment (strategy 1), the model predicted that 24 lambs and 19 ewes were struck each year with one ewe and two lamb deaths per year as a result of strike. The lowest cumulative strike incidence was achieved with strategy 7, which was able to reduce strike to 3 ewes and 5 lambs per year with no animal deaths. Where strike risk was higher or lower, the numbers of strikes were approximately doubled or reduced by half, respectively.

For flocks at low risk of strike, the lowest cost option (£468) was for farmers not to treat their animals prophylactically (strategy 1), and to simply treat reactively, due the relatively low number of animals struck (Figure 2). The highest cost strategy (£983) was early season treatment of ewes followed by subsequent treatment of both ewes post-shearing and lambs in mid-summer (strategy 7).

With moderate and high levels of strike risk, the cost of no treatment (strategy 1) was £1 137 and £2 133, respectively, over the course of the year. However, in both scenarios, organophosphate treatment of ewes only after shearing (strategy 2) was the highest cost strategy at £1 513 and £2 490, respectively, because of the cost of dip disposal, early season ewe strikes, and the high numbers of lambs struck. In both cases, treating ewes at the start of the blowfly season before shearing with a short-acting product, then treating the lambs with a long-acting product in June (strategy 6), was the lowest cost strategy (£719 and £1 092, respectively). Particularly when strike risk was high, the two strategies that used early season treatment of ewes (strategy 6 and 7), gave the lowest strike incidence over the period of high ewe strike risk, when their wool is at its longest and blowflies are increasing in abundance. Treating ewes at the start of the blowfly season with the short-acting product, resulted in the lowest cumulative incidence of ewe strikes and ewe deaths for all flocks, regardless of risk. For flocks at high risk, the cost difference between treatment strategies is larger, so selecting the most appropriate strategy to reduce cost becomes increasingly critical.

When the blowfly season was extended, under the moderate strike risk and no-treatment scenario, the cumulative number of ewe strikes increased to 22 and the number of lamb strikes to 36, with 2 deaths due to strike in each age class. Not treating prophylactically (strategy 1) was never the lowest cost option, even when risk was low (Figure 3). Under low and moderate strike risk scenarios treating ewes before shearing and then lambs in mid-summer (strategy 6) was again the lowest cost strategy (Figure 3). With high strike risk, treating ewes at the start of the season with the shorter-acting product, then treating both ewes and lambs with the longer-acting product (strategy 7) was the lowest cost treatment strategy (£1 717; Figure 3). Notably, for all risk scenarios, the lowest cost strategy always required the treatment of lambs with long-acting product A in mid-summer, as this protected them during the period of highest lamb strike risk.

Discussion

Given the low gross margins of many sheep rearing enterprises, identifying strategies which reduce cost while effectively managing disease incidence, is important. Blowfly strike is one of the most prevalent parasitic infestations on most lowland sheep farms in the UK (French *et al*., 1992). However, while considerable amounts of work have been undertaken to identify the prevalence, distribution and risk factors associated with strike, little work has related these data to economic impact. Here, our existing understanding of the patterns and risks associated with strike are incorporated into a model, parameterised with the current variable costs of prophylactic and therapeutic treatments.

The model suggests that when strike risk is low, not using prophylactic treatment and reliance on the timely identification and spot-treatment of struck animals is the lowest cost strategy; this is because with low numbers of strikes since deaths are unlikely to occur. Nevertheless, even under conditions of low strike risk, small changes in challenge, driven for example by weather conditions (Broughan & Wall, 2007a), or a failure to detect all struck animals leading to the deaths of one or more animals, can reverse this cost calculation. This economic assessment also takes no account of welfare considerations associated with tolerating even a low strike incidence. In all other risk scenarios considered, not treating animals prophylactically against strike is always among the most expensive approaches to strike management.

Lamb treatments had a particularly notable effect on strike and cost reduction, since lambs are the most abundant age-class of animals on the farm and are a highest risk over the period when fly abundance is greatest. Treatment of lambs with a longer-acting product, so that they are protected throughout the highest period of risk, was an essential component of all the lowest cost strategies. Not treating lambs in June, leaves them vulnerable during the period of highest strike risk when their wool is growing in length and they are accumulating larger nematode burdens (Broughan & Wall, 2007b). Lamb treatment at this time is also important because when ewe strike risk is reduced by shearing, lambs become the main available host for *L. sericata*, experiencing increased strike challenge (Broughan & Wall, 2007a).

At the start of the year, ewes are the most susceptible age-class and spring strikes in ewes represent a particular practical problem. At present, most farmers in the UK do not treat their ewes prophylactically against blowfly strike before shearing (French *et al*., 1992; Bisdorff & Wall, 2008). In not treating ewes at this time, farmers attempt to minimise costs by relying on their ability to identify and spot-treat any struck animals reactively, until they reach shearing. Shearing usually occurs between May and July and, once sheared, protection is conferred by the short fleece until, after some wool regrowth, when ewes can be treated with a long-acting product with protects them for the remainder of the season. However, the model used here suggests that in the moderate and high strike risk scenarios, early season treatment of ewes was always a component of the lowest cost strategy. The lowest cost strategies were the early season treatment of ewes combined with a June treatment of lambs, with the addition of a post-shearing ewe treatment when the blowfly season was extended. The nature of the product used for early season ewe treatment needs to be considered with care because there is the potential for insecticidal wool-residues to cause contamination in the water used for wool processing (Environment Agency 2009). Hence, the choice of a pyrethroid or a shorter duration IGR should be evaluated carefully. Although not considered in this static model, early season strikes, although relatively small in number, are also likely to be disproportionately important in terms of blowfly population dynamics relative to strikes later in the season, because they allow the *L. sericata* population to establish and contribute, potentially exponentially, to future generations. Any reduction in strikes in the spring period may therefore help to reduce fly-challenge and, potentially lamb strikes, later in the year. Future dynamic modelling to explore this effect will be valuable.

Strike incidence is likely to be highly sensitive to even relatively small changes in climate (Rose & Wall, 2011). Models of the impact of climate change have predicted that, in the UK, higher temperatures and warmer, wetter winters, are likely to lead to an extended blowfly season, with earlier spring emergence and a higher cumulative incidence of strike, as well as an increased risk of strike at higher altitudes (Rose & Wall, 2011). Such changes in the seasonal pattern of strike in the UK mean that understanding the changes in management that will be required, and its economic implications, is likely to become increasingly important.

Current blowfly management practices are often based on established historical practice, with little rational economic evaluation. The results presented here demonstrate that, unless strike risk is known to be low, not treating sheep against strike with a view to reducing variable costs is likely to be a high-risk strategy. Treatment based on an understanding of the seasonal pattern of fly abundance and sheep susceptibility, along with an understanding of the history of strike challenge on the farm, is likely to result in lower cost compared to waiting until cases of strike are identified visually.

The model assumes that treatment reduced strike risk to zero for the duration of its label claim; this may underestimate strike risks, since treatment efficacy can be reduced, for example by persistent rain. However, so long as this applies equally to all product classes, the assumption will not affect the relative outcome of the simulation or conclusion. Similarly, inflation of the precise treatment costs or expected losses is also likely to make little difference to the relative rank order of the economic impact of the different treatment strategies.

While rational choice of the most appropriate strike management strategy is essential in the context of cost-sensitive farm economics, welfare considerations also lend added importance to adoption of the most appropriate treatment decisions. Ultimately, best-practice animal management must be a compromise which reduces costs while safeguarding welfare and, notably, here the treatment strategies with the lowest cost were usually those with the lowest cumulative strike incidence, giving the best welfare outcomes.

Acknowledgements

We are grateful to Andrew Little whose interest and support stimulated the initial stages of the work presented here and to the helpful suggestions of two anonymous reviewers.

Declaration of interest

None

Ethics statement

Not applicable

Software and data repository sources

None of the data were deposited in an official repository.

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Table 1 *Seven different prophylactic insecticide use strategies used to model sheep blowfly strike management. The number of weeks of protection and the cost per ewe and lamb are shown for each strategy. Treatments A and B are able to prevent strike for 16 and 8 weeks respectively; organophosphate dips are assumed to give 8 weeks protection. All treatments are assumed to be 100% effective for the full duration of their residual activity.*

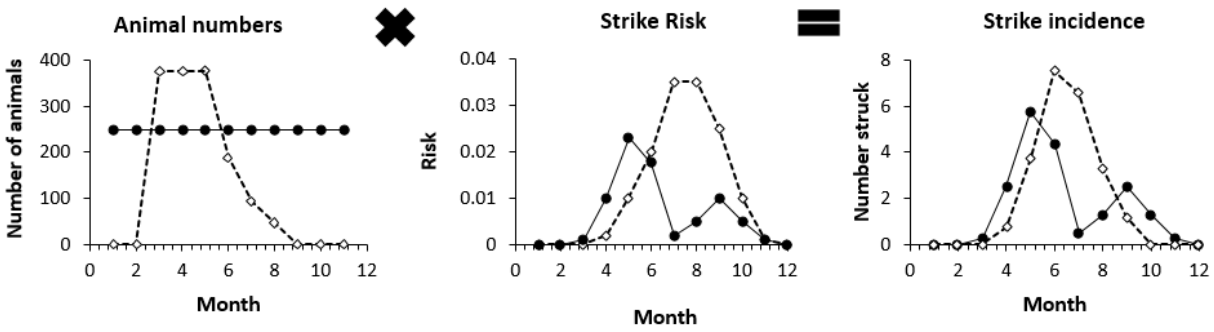
	Treatment strategy	Duration of protection	Cost per ewe	Cost per lamb
1	No treatment	0	0	0
2	Ewes: organophosphate dip (after shearing). Lambs: no treatment	Ewes: 8 weeks	£0.35 (+ £300 dip disposal)	0
3	Ewes: treatment A ewes (after shearing). Lambs: no treatment	Ewes: 16 weeks	£1.50	0
4	Ewes: treatment A ewes (after shearing). Lambs: treatment A (mid-summer)	Ewes: 16 weeks Lambs: 16 weeks	£1.50	£1.00
5	Ewes: no treatment. Lambs: treatment A (mid-summer)	Lambs: 16 weeks	0	£1.00
6	Ewes: treatment B (pre-shearing). Lambs: treatment A (mid-summer)	Ewes: 8 weeks Lambs: 16 weeks	£0.65	£1.00
7	Ewes: treatment B (pre-shearing) plus treatment A (after shearing). Lambs: treatment A (mid-summer)	Ewes: 8 + 16 weeks Lambs: 16 weeks	£0.65 + £1.50	£1.00

Figure captions

Figure 1 A graphical summary of the structure of the simulation model. Each week the number of each age class of sheep (open symbols represent lambs and solid symbols ewes) is multiplied by the expected probability of strike to estimate the numbers struck. When treatment is applied to any particular age class, risk is reduced to zero for the period of residual activity of the product according to the manufacturers label claim. Costs of reactive treatment, labour or animal losses are then calculated from the numbers of struck animals and added to any prophylactic treatment costs.

Figure 2 The cost (£GBP) incurred from blowfly strike in a modelled sheep flock of 250 ewes giving birth to 375 lambs in April under conditions of low (striped bars), medium (solid bars), and high (open bars) strike risk, with a blowfly season in which flies emerge in March and enter diapause in November.

Figure 3 The cost (£GBP) incurred from blowfly strike in a modelled sheep flock of 250 ewes giving birth to 375 lambs in April under conditions of low (striped bars), medium (solid bars), and high (open bars) strike risk, with a blowfly season in which flies emerge in February and enter diapause in December.



Animal numbers
Number of animals
400
300
200
100
0
0
2
4
6
8
10
12
Month
Strike Risk
Risk
0.04
0.03
0.02
0.01
0
0
2
4
6
8
10
12
Month
Strike incidence
Number struck
8
6
4
2
0
0
2
4
6
8
10
12
Month

Figure 1.

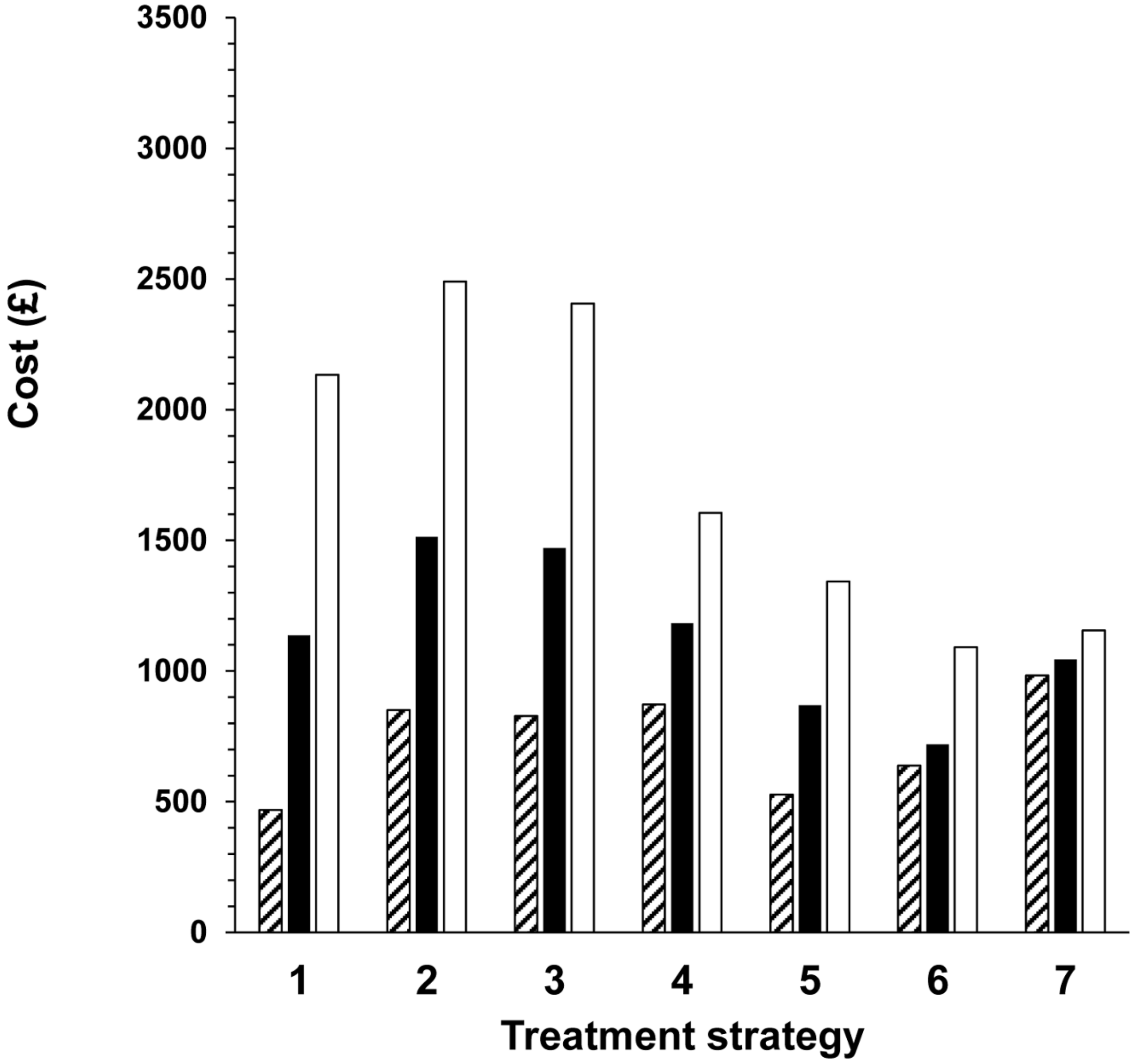
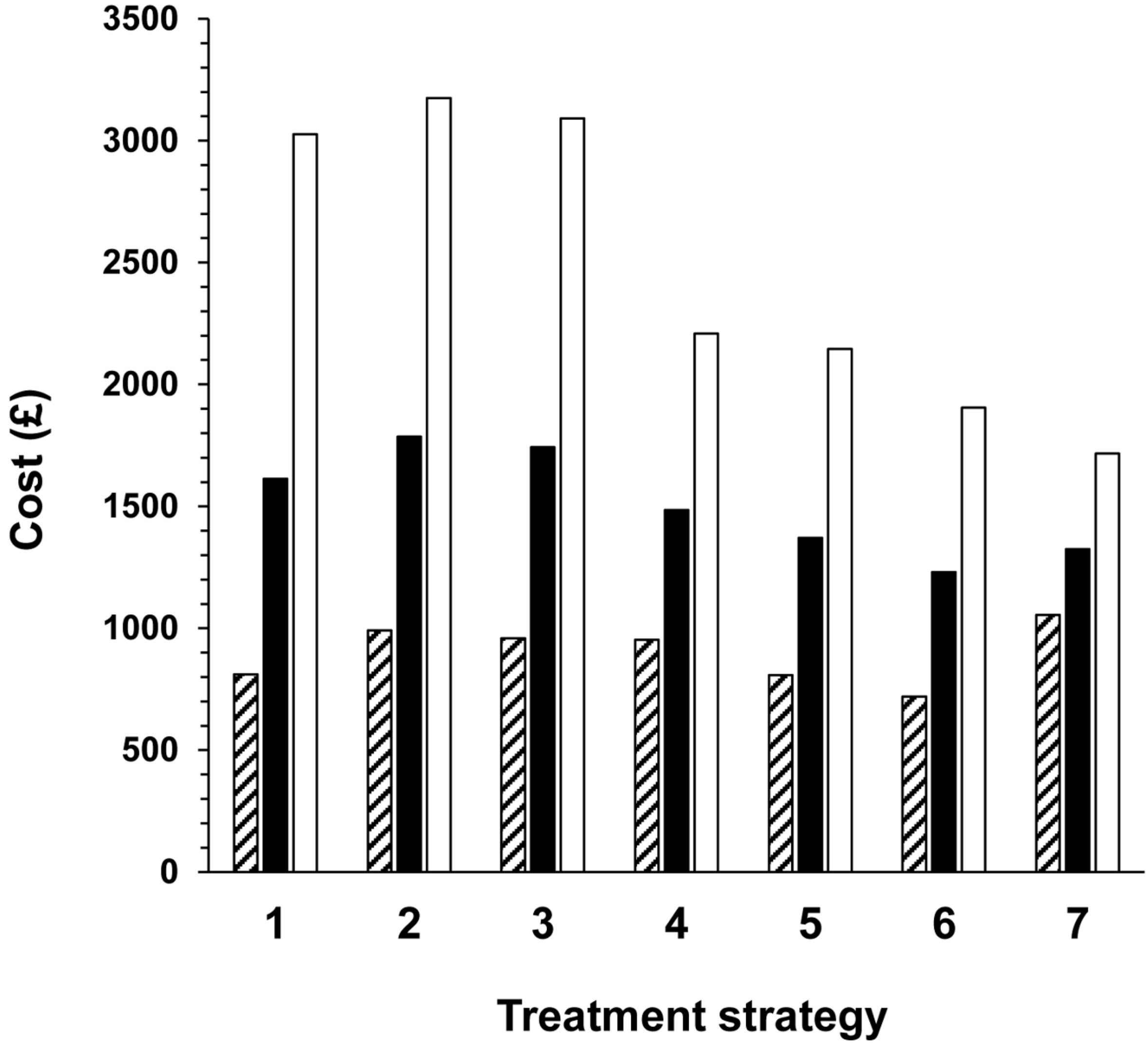

3500
3000
2500
2000
1500
1000
500
0
Cost (£)
1
2
3
4
5
6
7
Treatment strategy

Figure 2.



3500
3000
2500
2000
1500
1000
500
0
Cost (£)
1
2
3
4
5
6
7
Treatment strategy

Figure 3.